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WHITE PAPER

Methodologies for Sustainable HVAC Operation in Collection Environments

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In 2010, the Image Permanence Institute (IPI), a department of the College of Imaging Arts and Sciences at Rochester Institute of Technology, Rochester, NY received funding from the U. S. National Endowment for Humanities, to investigate new methodologies for sustainable management of collection environments. Collections of enduring research value and cultural significance reside mainly in libraries, archives, and museums that are under pressure to reduce their use of energy. While is widely recognized that providing a proper environment is the most important element for preservation, HVAC operations are under scrutiny. In response, institutions are considering a variety of strategies to minimize energy use, such as moving from a static environmental management approach, where macro-environmental temperature and humidity settings remain stable and constant, to a dynamic approach involving methodical nightly, weekend, or seasonal settings adjustments. IPI's research addressed the lack of systematic study of what happens to collection materials when short-term climate changes occur. Looking to common material-enclosure configurations, such as books on shelves, and paper documents and photographs in boxes, IPI's research explored several key questions: How do temperature and humidity changes propagate through objects and collections? How do seasonal changes affect collections? How can collection managers assess the risks or benefits of dynamic environmental changes that occur in a repetitive pattern over long periods of time?

The thrust of this paper is to summarize new findings regarding thermal and moisture transfer between materials and collection environments as they were developed during the NEH-funded research project awarded to IPI in 2010. The investigation and results are presented in this paper in a concise format and with a general audience in mind. A more detailed final report was provided to NEH in the form of the Final Activity Report. Findings from this project are based upon extensive laboratory testing and field experimentation. IPI's research provides new and significant insights into the dynamic relationship existing between the changing conditions of the macro-environment, the micro-environment surrounding a collection object, and the object's core. It is believed that the gained knowledge will enable and support profound changes in the way HVAC operations are regarded and it has already led to further research in the field of environmental control for the preservation of library, archive, and museums' collections.

The notion of proper environment for collections has evolved in significant ways. The current thinking underscores the preference for cool/low temperature for storing collections of organic materials, and must notably, the trend is to accept more readily that (1) little benefit comes from steady temperature, and (2) steady storage environment in terms of temperature and humidity is not always considered necessary for quality preservation. A renewed interest in these ideas was prompted by the appeal towards sustainable preservation practices. Often libraries, archives and museums are confronted by the fact that their resources are limited. While maintaining proper storage for their collections may be a very expensive proposition, applied research developed at IPI demonstrated that opportunities exist for reducing climate control energy costs by exploring the feasibility of dynamically managing the collections' environments.

Project activities were divided into laboratory research, field experiment, and data analysis, and have produced empirical data on the rate at which temperature and RH changes propagate into micro-environments and into the core of typical library and archive materials. Test samples encompassed photographic prints, matted photographic prints, office paper stacks, large-size paper stacks, and books, along with various types of enclosures (drop-front cardboard box, museum case, portfolio box, metal office file cabinet, and metal flat-file cabinet). Overall the research investigated to which extent temperature and RH short-term (hours) and sustained (over a period of several months) changes propagate through typical library and archive collections.

In the laboratory, test samples were exposed to five types of temperature and RH profiles: (1) weekly "square wave" temperature and RH profile, (2) weekly "ramped" temperature and RH profile, (3) weekly temperature adjustments profile without RH control, (4) weekly temperature adjustments profile at constant RH, and (5) stepped RH profile at constant temperature.

The first goal of the experimentation was to evaluate the impact of *intentional* temperature setbacks that mimic a potential avenue for energy savings. The premise of the approach was that setting the temperature to a lower level during the winter nights and weekend would lead to less energy consumption, and allowing higher temperature during the summer nights could also potentially reduce energy costs. To that end, the first two types of weekly profiles were designed after typical library operations including daily unoccupied hours. It is during these "closing" hours that temperature setbacks were implemented. It was also assumed that no change in absolute humidity would occur during these periods and therefore the RH was adjusted accordingly to maintain constant moisture content in the space. Based on this design, the test samples were exposed to cycling temperature and RH in such a way that the RH profile was the "mirror image" of the temperature profile. Each temperature decrease was synchronized with each RH increase, and vice versa.

The exposure of the test samples to a series of temperature and RH weekly profiles enabled IPI to estimate to which extent materials "sensed" macro-environmental changes sustained for 8, 16, and 32 hours. The response to temperature setbacks of 5°C (9°F) were studied, and the RH was adjusted according to the temperature profile to maintain a constant dew point at all times in the space. Overall, the data collected during these experiments re-affirmed that temperature change propagates through the test samples at a relatively fast rate. The outside surface of an object, as well as its core, does sense the full magnitude of a temperature change after several hours. It was also noticed that the impact of common enclosures has little effect in postponing temperature equilibration.

At the same time, the propagation of moisture through enclosures, and through the objects themselves appeared to be slow enough that both the enclosures and objects themselves mitigate the impact of short-term RH changes. By nature, the rate of moisture diffusion is as fast as the moisture gradient is great, and is strongly dependent upon the "porosity" to moisture of enclosures, and objects' materiality and physical format. Inevitably, the slow rate of moisture diffusion creates a heterogeneous but continuous distribution of moisture throughout an object. Data collected during the research implies that major differences exist between the "skin" of an object and its core. In reality, the outside of an object always feels to some degree the effect of ambient RH cycling, while internally the object feels very little change. In practice, the information developed during the research quantifies the benefit of "tight" enclosures (e.g., museum cases, portfolio boxes) in comparison with cardboard boxes for mitigating the impact of ambient RH short-term fluctuations, and these empirical results reaffirm the significant role that specific enclosures can play, as the "last" moisture barrier when adverse RH conditions periodically occur.

Further examination of the measurements collected in the middle of the test samples also merits our attention. While the amplitude of RH change is small in all the situations tested, its frequency reveals that the fluctuation is more dependent on temperature than on ambient RH change. Data indicate that the RH at the core of the test sample correlates with the temperature profile rather than with the ambient RH profile. This observation supports the assumption that temperature cycling has the potential for "forcing" moisture into or from a hygroscopic object such as a book based on the fact that for each temperature a thermodynamic equilibrium exists that defines how much water there is inside the object at a given RH. Further experimentation conducted at IPI showed that the presence of a sufficient amount of books inside a closed environment is capable of stabilizing RH fluctuations otherwise caused by temperature cycling. It is believed that small quantities of moisture released or adsorbed by the hygroscopic components of the books responding to temperature cycling contribute efficiently to maintaining a steady ambient RH. Such behaviour, merits further investigation and may provide opportunities for using collections' thermodynamic behaviour to improve "passive" humidity control of collections' environments.

Overall, the laboratory research findings reaffirmed that macro-environmental short-term fluctuations are not experienced fully by collection objects, which indicates that there is merit in pursuing alternative ways for dynamically managing collections' environments through the implementation of temperature and RH setbacks and/or HVAC shutdowns for the purpose of reducing energy consumption. In addition, several other management options emerged from the research. They consist of either slowing down – even further than the use of specific enclosures are able to when needed for preservation purposes – the rate of moisture equilibration of collections' materials in order to avoid adverse RH levels, by using specific energy saving RH profiles. Of particular interest, it was found during the research that the use of a stepped RH profile may have the potential to delay moisture equilibration of collections' materials. Data developed during this research are being further evaluated through the implementation of a wide range of HVAC management scenarios with the ultimate goal of minimizing the risk of exposing collections to periods of high RHs and dryness due to seasonal humidity cycling, while potentially allowing for greater energy savings.

This research focus was strongly supported by the field experimentation conducted at the RIT's Wallace Library. The findings related to the impact of intentional HVAC shutdowns on the collections' environment, the materials microclimate (inside enclosures), and the materials' internal RH led to the following observations: (1) nightly and weekend HVAC shutdowns caused only small changes in storage temperature, and did not alter ambient RH levels, (2) data support the idea of expanding the HVAC shutdown period in order to further decrease energy costs, (3) data demonstrated consistently that the micro-climate RH and RH measured at the core of the materials lagged behind ambient RH, and (4) most importantly, seasonal RH changes leading to either high humidity levels or dryness have a definite impact on collection materials' equilibrium moisture content.

In the framework of this field experiment, it is possible to conclude that a collection's materials do not feel short-term "peaks" and "valleys" in terms of humidity changes, the priority for managing the collections' environments is to minimize the effect of the seasonal RH cycle. This direction of research is the central focus of IPI's current NEH-funded research project entitled *Understanding Moisture Equilibrium for Humanities Collections: A New Path to Sustainable Humidity Control*.